HYDRO-ELECTRICAL DEVELOPMENT
ON THE
COLUMBIA RIVER AT THE DALLES, OREGON

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PROPOSED HYDRO-ELECTRIC DEVELOPMENT

On The

COLUMBIA RIVER AT THE DALLES, OREGON.

A THESIS

Presented by

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Preface.

Owing to the enormity of the project, it has been impossible to go into the details of the dewign. The thesis may be considered more or less as a preliminary design from which more accurate plans and details may be evolved.

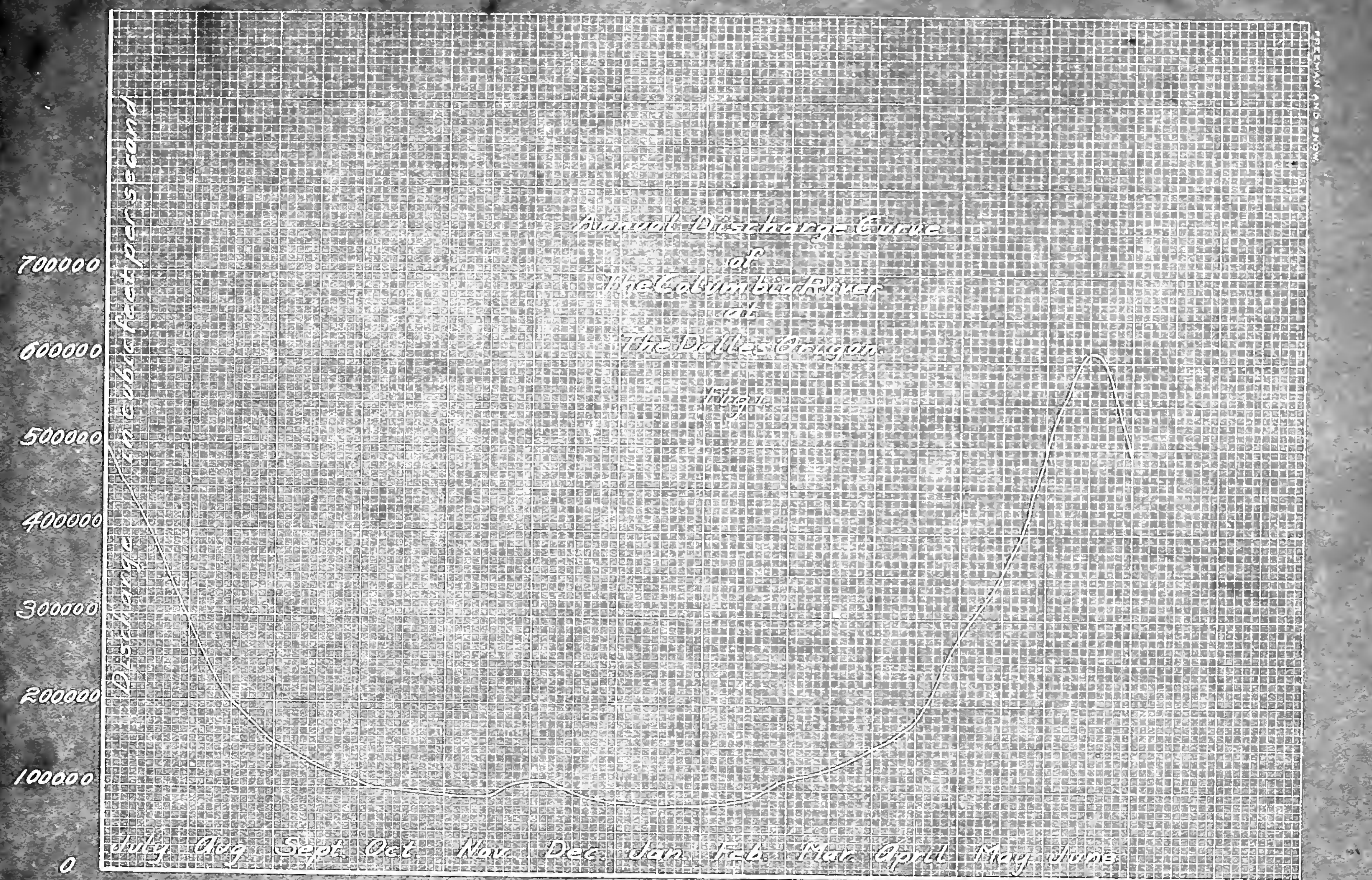
Only standard machinery and standard auxiliary apparatus have been used, no original designes being attempted. The Keokuk water plant which has been in successful operation for practically a year is probably the only other hydro-electric station of such large capacity, and it has been deemed advisable to use it as a reference.

Table of Contents.

Location.

The proposed power site is located on the Columbia River about ninety miles from the City of Portland, and one hundred and eighty seven miles above the mouth of the river. The Columbia River is now navigable with ease, for deep draft ocean vessels to the mouth of the Willamette River, ninety miles above the mouth, and for the remaining eighty nine miles, is navigable at all times except in extreme high water stages, for vessels of eighty foot draft, the power site being at the present head of navigation.

The proposed scheme is to divert the water by means of a canal on the Washington side of the river at a point which is known as Five Mile Rapids, about five miles above the City of The Dalles, Oregon. The river at this point suddenly contracts from a width of low water of about sixteen hundred feet to a width of about two hundred feet, and remains nearly this narrow throughout the length of Five Mile Rapids



FREEMAN AND SNOW.
Annual Discharge Curve
of
The Columbia River
at
The Dalles Oregon
Fig.
Discharge in cubic feet per second
700000
600000
500000
400000
300000
200000
100000
0
July Aug Sept. Oct. Nov. Dec. Jan Feb. Mar. April May June

or to Big Eddy, about one and one half miles below. The proposed location of the power house is at the above mentioned "Big Eddy".

The Columbia River is one of the largest streams in the United States. Above the power site under consideration, it drains an area of approximately two hundred and fifty thousand square miles, much of which is mountainous. Many of its tributaries are fed by melting snow and glaciers in the high altitudes, to which is attributed its most prominent characteristics of flow, namely; the regularity of the occurrence of its annual flood in June when the rainfall on its drainage area is very small, and its general steadiness of flow, free from the sudden and unexpected floods and droughts so common to Middle West streams at almost any season of the year. Records of the flow of the Columbia River are available for the past thirty three years.

Curve sheet No.1 shows the average hydrograph for years 1901 - 1912 (1911 omitted).

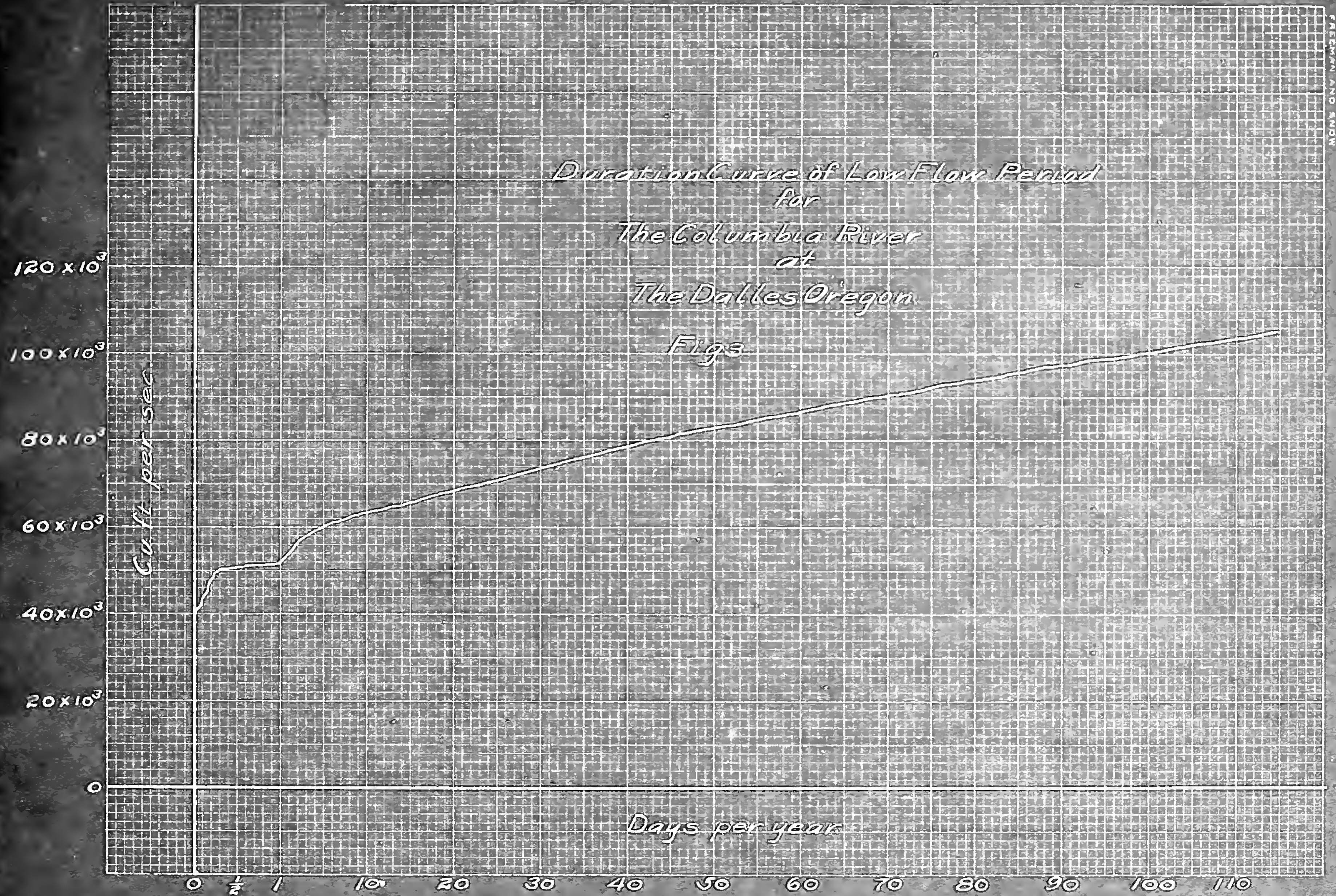
Annual Average Duration of Flood Curve
for
The Columbia River
at
The Dalles, Oregon
Fig. 5
Cubic feet per second
Days per year
1500000
1400000
1300000
1200000
1100000
1000000
900000
800000
700000
600000
500000
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
FREEMAN AND SNOW

What may be called the " normal flow period" of the river, will be seen to extend from September to about March. Two periods are particularly important in the study of a stream for power purposes - the flood period and the low water period.

By reference to Curve Sheet No.1, it will be seen that June is the normal flood month and an examination of the records has indicated that the time of occurrence is very regular. From diagrams, it has been found that the maximum flood on record occured in 1894, and a magnitude of 1390000 cubic feet per second. Curve sheet No. 2, shows the annual average duration of floods of various magnitudes in days per year. Each point on the curve was obtained by dividing by thirty two the total number of days during thirty two years in which a given flood had been exceeded.

Flow of River.

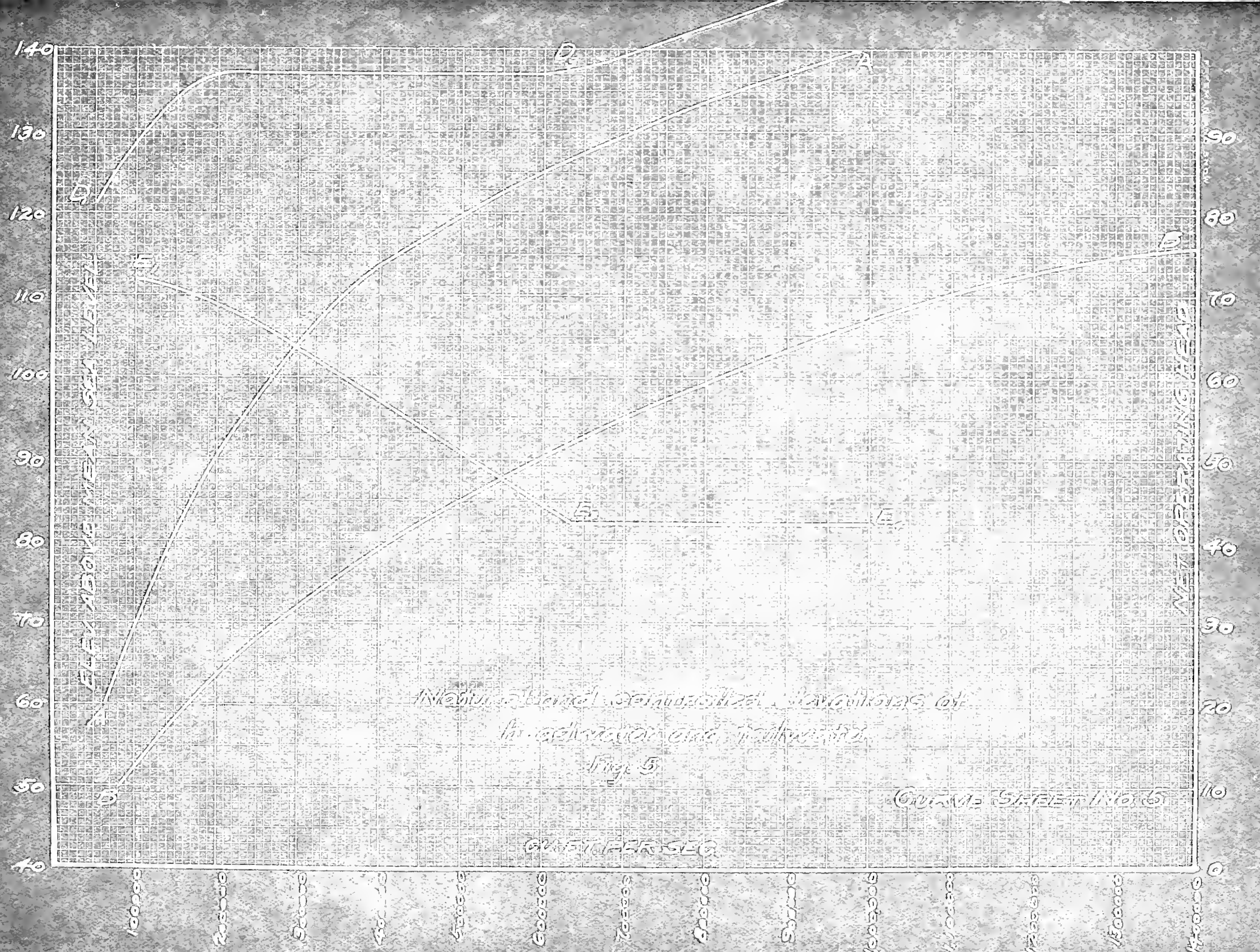
As will be seen from Curve No.1, low water



Duration Curve of Low Flow Period
for
The Columbia River
at
The Dalles Oregon
Fig 3
Cu ft per sec.
120 x 10³
100 x 10³
80 x 10³
60 x 10³
40 x 10³
20 x 10³
0
Days per year
0
½
1
10
20
30
40
50
60
70
80
90
100
110
FREEMAN AND SNOW

in the Columbia River occures during the winter time when the smaller tributaries are largely ice bound, and the extreme minimum flow probably occures during the few days when the river and its tributaries are freezing, the freezing process acting in a two-fold manner to reduce the stream flow, namely; by drawing a large amount of water from the stream and converting it into ice, and second, by so increasing the resistance of the river to the passage of water as to cause the general water level throughout the length of the stream and its tributaries to rise somewhat, thus deducting from the flow the volume of water necessary to increase the level.

The extreme minimum flow occured in the winter of 1912, the flow dropping to a value of 40000 cubic feet per second. Curve sheet No.3. shows the duration curve of minimum flows similiar in all respects to Curve No.2. The conclusion to be drawn from the foregoing is that it is very improbable that the flow will fall below 50000 second feet.



ELEV. ABOVE MEAN SEA LEVEL
NET OPERATING HEAD
CU. FT. PER SEC.
headwater and tailwater
Fig. 5
CURVE SHEET No. 6
140
130
120
110
100
90
80
70
60
50
40
0
10
20
30
40
50
60
70
80
90
100000
200000
300000
400000
500000
600000
700000
800000
900000
1000000
1100000
1200000
1300000
1400000
A
B
D
E

Available Head.

In Curve sheet No. [illegible], the Curve BB shows the elevation above mean sea level of the water surface in Big Eddy for the entire range of flow of the river, where a total fluctuation in level of about seventy feet will be observed. This elevation will remain essentially unchanged subsequent to the construction of a power plant.

The head water elevation, however, is subject to control by means of a dam. In the same diagram, the curve AA shows the normal elevation of the water at the head of Five Mile Rapids, indicating a total fluctuation of about ninety feet.

The difference in elevation at the dam site and power house site, represented by the vertical distance between curves AA and BB, or the present natural fall at all stages of the river, is shown by curve CCC, the scale being at the right of the diagram.

To maintain a constant operating head at the power station would require an artificial control of the head water elevation by means of

dam in such a manner as to make the head water curve parallel with the tail water curve EE. However, since this project requires a canal about one and a half miles long, it would be uneconomical to do this. Since the power of the stream is proportional to the product of discharge by head, it is best to utilize a greater head under low water conditions, and thus obtain a greater amount of power, allowing the additional discharge at higher river stages to compensate for the reduced head by the additional machinery.

It is a well established fact that a turbine operating at other than its normal speed or speed of best efficiency, is subject to erosion or pitting of the metal of the turbine buckets proper, the cause of which action is not fully explained. In selecting a maximum head therefore, for this station, it is best to determine what minimum head can be realized, and then to select a maximum or low water head differing from the minimum by an amount such as to

keep the two head within the practicable limit of operation of a turbine.

Minimum Head.

The head in hydro-electric power stations is controlled by the height of the back water. Running parallel to the river are two railroads, one on each side. Backwater computations have shown that by slightly raising the grade of each, it would be possible to bring the head water elevation to 131.00. This corresponds to a discharge of 1000000 second feet, the maximum flood for which the plant has been designed. Under these conditions, the net operating head which could be utilized at the power station after deducting for a loss or fall in the water surface of the canal, would be about forty-two feet.

Maximum Head.

With this assumed minimum head, the maximum practicable range of satisfactory operation would limit the maximum head to about seventy feet with the turbines adjusted to operate at best efficiency at about sixty feet head. The

The minimum tail water elevation at ordinary river stages (not extreme minimum) is about elevation fifty, which with seventy feet head, and by allowing for a drop in the water surface of the canal, would require a head of water elevation of about one hundred and twenty five feet under low water operating conditions. The curve E ,E ,E ,E , of fig. 5 shows the net operating head for all conditions of flow.

As stated previously, the maximum flood has been taken as 1000000 second feet. It is true that a higher discharge has occured, but reference to Curve sheet No.3 will show that a flood of 1300000 second feet has occured only once in thirty-two years. It is good engineering as well as almost universal practice, to ignore extreme and remote conditions and to accept an interruption of service, should these conditions ever again occur.

Power.

Low Water Conditions: The power of the stream based upon the previous assumptions, namely;

50000 second feet minimum flow and seventy feet maximum simultaneous operating head, would be about 330000 horse power, delivered to the generators. This is based upon 90 % turbine efficiency. The power which could be delivered to the switchboard after allowing for generator losses would be approximately 300000 horse power.

High Water Conditions: As the power of a hydraulic turbine decreases rapidly with dropping head, it is necessary at high water, in order to maintain the assumed delivery of 300000 horse power, that additional turbines be installed. Due to the immense size of this proposed power plant, the machinery to be installed would, in order to reduce the total number of generating units to a reasonable figure, need to be very large. As the basis upon which to estimate, the cost of installation, a generator of 20000 Kilowatt normal rating, driven by a turbine of 32000 horse power capacity at 70 foot head, will be chosen. Eleven of these units would be required to deliver 300000 horse power at 70 foot

[illegible] with overload capacity of the turbines in service, at 43 head, twenty one units would be required. This corresponds to high water conditions.

Power House.

As stated before, the power house will be located on the Washington side and will be of solid masonry construction. It will be 1300 feet long, 140 feet wide, and 200 feet above its foundations. All the high tension rooms and transformers will be isolated by means of steel doors. Provision will also be made so that in case of fire, oil can be discharged into the stream. Tunnels for machinery such as oil compressors and storage will be built in the substructure. Also a standard track will be run into the side of the building together with a turntable for use in installing machines.

Turbines.

The normal head on the turbines is 60 feet. Under this condition, as stated before, 330000 horse power at 80 % efficiency would be delivered to the generators. Since the Keokuk wheels

are the largest which can be shipped, it is necessary to limit the turbines to this size and to choose such a capacity as to compare favorably with the specific speed of the Keokuk turbines. Calculations have shown that a 30000 horse power wheel at 80 R.P.M. used in this installation will be similar to those of Keokuk, the only changes necessary being in the mechanical details owing to the increased stresses. Practice has shown that efficiency of 88 per cent under normal conditions, are not uncommon and the computations of this installation will be based on this efficiency under 60 foot head, and 75 % gate opening. Since the available power is expressed by

$$\frac{Q \times H \times \text{eff.}}{8.8}$$

we can determine the discharge per wheel as

$$Q = \frac{30000 \times 8.8}{60 \times .88} = 5000 \text{ second feet.}$$

The efficiency of the generator at full load will be specified at 96 % , and with 30000 horse power delivered to them by the turbines, a net

[illegible] output per generator of

(3) 5000 x [illegible] x .80 = [illegible] H.P.

will be obtained. In order to develop the entire energy of the stream, eleven wheels will be in use at this head.

When the head drops to 40 feet, then, considering the same gate setting, the discharge through the turbines will equal

(4) $$\frac{Q}{5000} = \frac{(40)}{(60)} \qquad Q = 4000$$

However, at the low head, the turbines will be overgated and an increase of 25 % in the discharge will be considered. The efficiency will also fall off, and on a tentative basis for calculation, will be assumed to equal 70 %. The horse power output will then equal

(5) $$\frac{5000 \times 42}{8.8} \times .70 = 16700 \text{ H.P.}$$

In order that [illegible] horse power may still be supplied, twenty turbines will then be necessary.

At the 70 foot head, the discharge for a $\frac{3}{4}$ gate opening will equal

(6) $$\frac{Q}{5000} = \frac{(70)}{(60)} \qquad Q = 5400$$

At this point it will be necessary to [illegible] the turbines and a flow [illegible] of 5[illegible] cubic feet will be assumed. Then the output of the turbine, assuming 80 % efficiency will equal

(7) $\frac{7000 \times 62}{[illegible]} \times .80 =$ [illegible] H.P.

Eleven turbines will be required to furnish the 730000 horse power.

Generators.

The generators are of the revolving field type. Owing to the improvements of 60 cycle apparatus it has been decided to adopt this frequency. The revolving parts will be supported by a thrust bearing underneath the generator. Three phase currents at 12000 volts will be generated.

Excitation.

The required excitation will be about 4000 K.W. and will be provided by motor generator sets. The motors will be operated by a vertical water wheel-driven alternator, with direct connected exciters. In order to provide for emerg-

ery, two 1000 K.W. 1200 volt [illegible] will be installed. Each main generator will be supplied with one motor-generator set. Fourteen induction and six synchronous motors will be used. Transformers are connected to the low tension 11000 volt busses and step down to 220. [illegible], and the motor generator sets to be operated from the main generator. When the power factor is low, the synchronous motor can be over-excited and operated from this low tension bus for line regulation. A storage battery is also provided for extreme emergencies. Auto transformers are used for starting, two taps being used. [illegible] oil switches will be used for all switching, and the oil switches for half and full taps will be electrically interlocked. Much emphasis has been laid on the importance of providing for emergencies in the exciter layout, for a short delay in such a station is of extreme importance.

Transformers.

The transformers will be of 10000 K.V.A.

[illegible] will [illegible]
from [illegible]. It will [illegible]
[illegible] January
[illegible]formers. [illegible] and low tension bus-
[illegible] with the switches between
them, [illegible] transformers feeding into [illegible]
[illegible]. The transformers will
be protected [illegible] means
of overload relays. Potential and current trans-
formers will be placed on the low tension side
of the [illegible] and also on the outgoing lines.

CANAL.

The canal for this project will be about one and one half miles long and will be dug out of solid rock. No puffer dams will be required at ordinary stages and a large amount of excavated rock can be wasted along the sides of the canal to form rock filled walls along the canal in order to retain the water which would stand above the natural rock surface and to protect the T.P. & T Railroad. These rock filled walls will be paved on the water side with con-

[illegible]

[illegible] = 55000 [illegible] feet.

[illegible] canal will carry

[illegible] = [illegible] feet.

[illegible] of [illegible] 10 [illegible] 135.00, the canal will [illegible] depth [illegible] four feet, with a batter of [illegible] inch per foot. The width of the canal at the bottom will equal three hundred feet. The [illegible] will [illegible] and drop [illegible] below elevation 155.30 The area of the canal then equals

$$305 \times 20 = 6100 \text{ square feet.}$$

The velocity of a discharge of 55000 second feet equals

$$\frac{55000}{6100} = 9.0 \text{ feet per second.}$$

For such a canal the coefficient of roughness is about .025. The wetted perimeter equals

$$300 + 41.28 = 341.28$$

and the hydraulic radius equals

$$\frac{6100}{341.28} = 17.90$$

[illegible]

[illegible] velocity.

When the water [illegible] elevation [illegible],

then the velocity will equal

[illegible]

The top of the [illegible] elevation 100.00 will be on [illegible]. In this case the wetted perimeter equals 41.7 [illegible] hydraulic radius 14.4. A slope of 1.00 feet gives a velocity of [illegible].8 feet per second which [illegible] with the previous calculation.

In order [illegible] the velocity thru the rock as small as possible, the canal will be excavated to a depth of elevation 80.00 at the entrance of the power house and the width will be increased as much as practicable.

Dam.

The rock at the site of the dam is composed of hard basalt, usually of columnar structure and quite seamy. The proposed dam is of the rock

[illegible]
[illegible], including [illegible]
[illegible]
[illegible] to design this type of dam for overflow
and [illegible] given the channel is to be con-
tracted [illegible]
[illegible] will [illegible]
construction purposes, the [illegible] filled dam pre-
viously mentioned being built well above the
maximum flood level. The diversion channel has
already been described, but at the [illegible] is pro-
vided a removable type of dam, the purpose of
which is to regulate the river flow.

This removable dam is similiar to those built for the emergency dams on the Panama Canal, except for the substitution of a permanent bridge instead of the swing spans as on the Panama. The dam will consist of large concrete piers spaced one hundred feet center to center with the concrete arched sills, and at the top heavily reinforced concrete beams or horizontal steel girders enclosed in concrete, between the piers.

The [illegible]

[illegible] will be [illegible] placed [illegible]

horizontal [illegible] the [illegible]

[illegible] position [illegible]

[illegible] the [illegible]

ders to [illegible] giving [illegible] each pair of gir-

ders is made to revolve on its hinges, the up-

stream end of the girders being raised up or

let down as desired. When the [illegible] girders

are lowered into place, the gates are allowed

to slide down on the girders until they reach

their proper position. (See Drawing.)

The bottom of the concrete sill will be

at elevation 100.00, while the middle girders

will be at elevation [illegible]. The rock between

the removable dam and the river bed will be ex-

cavated, giving a slope of about 10 feet in

1000. Assuming a maximum velocity of 20 feet

per second and considering a maximum discharge

of 1400000 second feet, then the required area

equals

$$A = \frac{1400000}{41 \times 20} = 1750 \text{ square feet.}$$

T[illegible] [illegible] [illegible] [illegible] [illegible]ach.

[illegible] will consist of a steel girder. This girder will consist of a ½" web, with 2 - 8" x 8" angles and 4 - 1" x 17" cover plates. Stiffener angles 4" x 4" x ½" will be spaced every six feet.

The gate will comprise a heavy steel sheathing supported by I-beams 30' - 1" in length. The spacing of these I-beams will vary from two feet at the bottom to seven feet at the top. The sheathing will consist of ¼" steel and will be reinforced by straps ½" x 6" placed diagonally on the back.

The inclined [illegible] girders will consist of two web plates, with four angles placed at the corners and then covered with cover plates, generally known as box girders. Calculations have shown that web plates five feet deep and one inch thick will be needed, considering a 30" spacing between them. Four 8" x [illegible] x 1" angles and eight 30" x 1" cover plates will also be required.

[illegible]
from [illegible] the depth of the gir-
der will also be changed from five feet at the
bottom to two feet at the top.

Transmission.

The transmission lines will consist of steel
tower construction on the private right
of way. Duplicate three phase lines and one
ground wire will be arranged. Only four trans-
mission lines have been computed. The follow-
ing table shows the size of wire and power de-
livered.

Town	K.W.	Wire Size.
Umatilla	30000	No. 0000 B & S
Portland	20000	No. 0000 B & S
Salem	5000	No. 2 B & S
Eugene	5000	No. 4 B & S

Market for Power

One cannot expect that a market for such
a tremendous amount of power already exists.
However, manufacturing industries already re-
cognize electrical operation of factory mach-
inery as the accepted method. Coincident with

[illegible] development of [illegible] [illegible] ing and [illegible] [illegible], [illegible] [illegible] [illegible] remark-able readjustment of old manufacturing process-es and the [illegible] development of chemistry and industries made possible only by the principle of the electrolytic [illegible] and electric arc, why not render some of [illegible] industries [illegible] [illegible] [illegible] [illegible] [illegible] development?

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